Distributed Air-Ground Traffic Management (DAG-TM)

Steve Green

Mark Ballin

David Wing

Distributed Air Ground Traffic Management (DAG-TM)
Industry Workshop
May 22, 2000

Outline

- Introduction
- DAG-TM Overview
- Airspace-Problem Approach
- DAG-TM “Concept Elements”
- DAG-TM Project Status

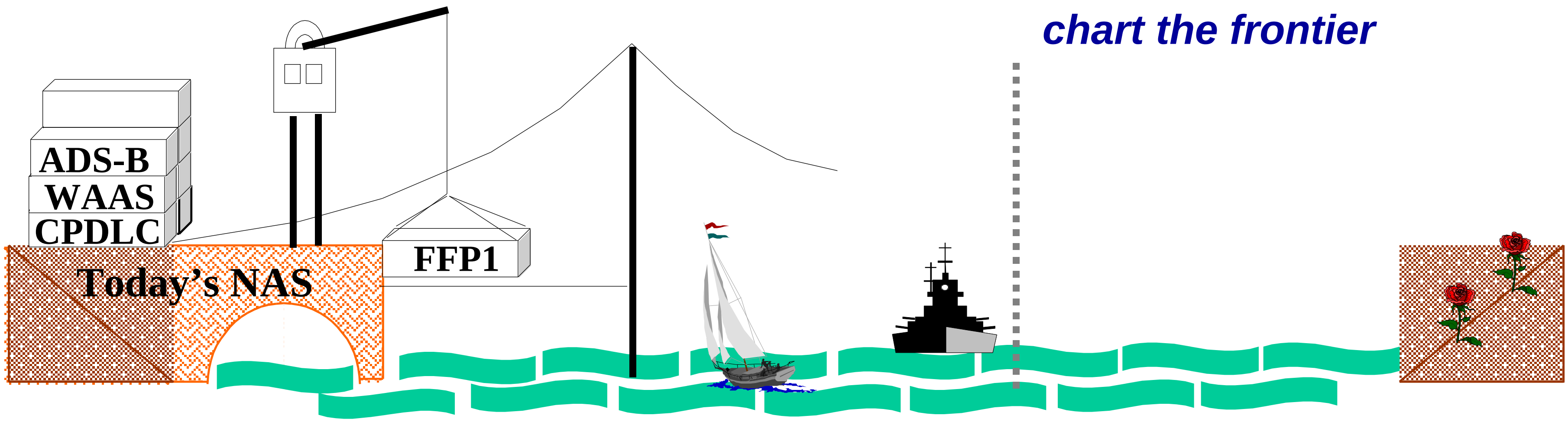
What is the Future of ATM ? and what is NASA's role?

In building a bridge to Free Flight,

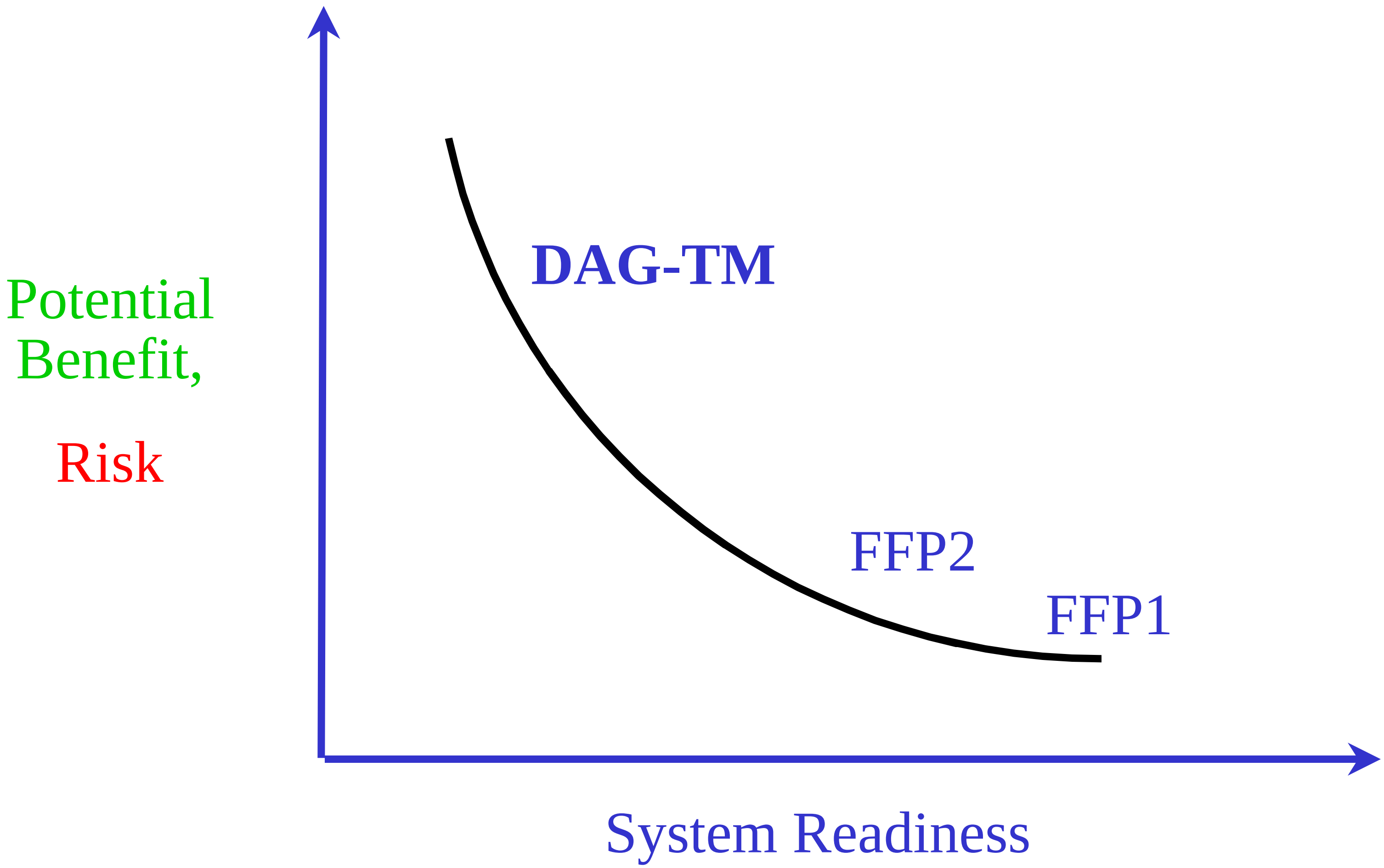
we can't just evolve from today's NAS,

we need to choose where to evolve to.

NASA's role is to chart the frontier



DAG-TM R&D



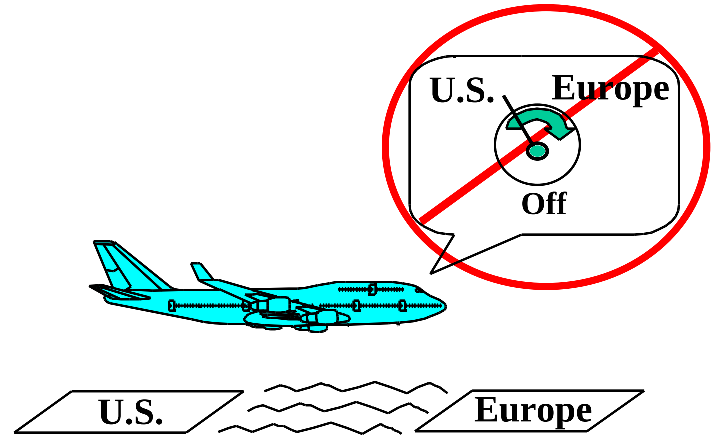
Integration, Integration, Integration!

- Future ATM improvements require more than just new technologies, they require integrated solutions
- CNS-ATM integration is more than the sum of the parts… its the future of global interoperability
- The economics of flight operations are driven by ATM constraints.
- User goal:
  - Maximum return on investment
  - Maximum value for modernization.

Flexibility
Minimum Deviations

$$\text{Value of Modernization} = \left\{ \frac{\text{Benefit}}{\text{Cost}} \right\}$$

Mandated Equipage*
Fees and Taxes



Global Interoperability

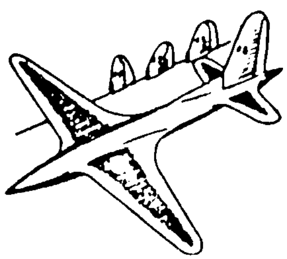
We must define inter-operability today to effectively design avionics of tomorrow.

CNS-ATM is Multi-Disciplinary

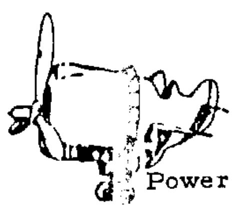
~~Component Optimization~~

System Optimization

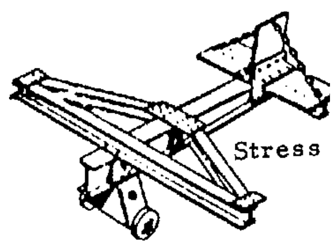
- Example: Aircraft Design



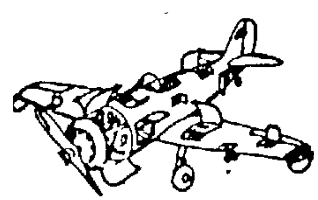
Aerodynamics



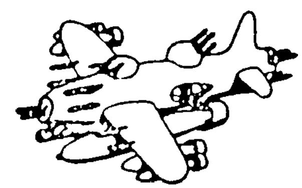
Propulsion



Structures



Serviceability



Armament (Air-to-air Separation)

Distributed Air Ground (DAG) Core Team (Cross-cutting attack on DAG)

Disciplines / Applications	Human Factors	Decision Support Engineering	System Engineering	CNS Engineering
Flight Deck				
Flight Planning				
Surface ATC				
Terminal ATC/TFM				
En route ATC/TFM				

Distributed Air Ground (DAG) Core Team

- Mark Ballin
  - Flight deck engineering
- Karl Bilimoria
  - CD&R engineering
- Greg Carr
  - Terminal engineering
- Dave Foyle
  - Human factors
- Steve Green
  - En route TFM / ATC operations
- Irene Laudeman
  - System engineering
- Gus Martzaklis
  - CNS engineering
- Ev Palmer
  - Human factors
- Sandy Lozito
  - Flight deck human factors
- Walter Johnson
  - Flight deck human factors
- John Robinson
  - Terminal engineering
- Phil Snyder
  - System engineering & benefits
- Del Weathers
  - Operational concepts
- David Wing
  - Flight deck engineering
- Rick Zelenka
  - Terminal engineering

DAG-TM Overview

- DAG-TM Definition
- Scope and Assumptions
- Approach
- Targeted Benefits

DAG-TM Definition

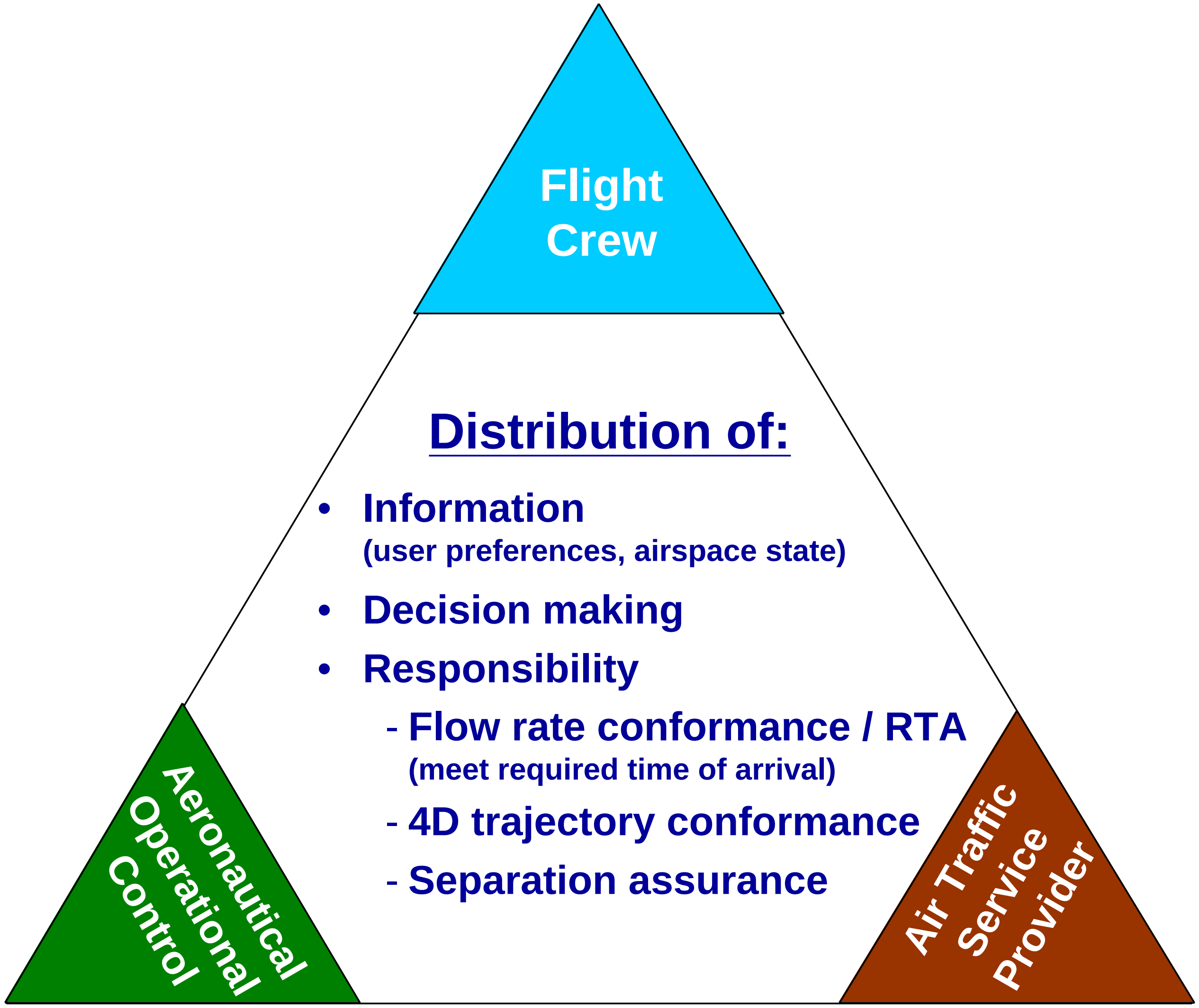
Distributed Air-Ground Traffic Management (DAG-TM) is a National Airspace System concept in which Flight Crews, Air Traffic Service Providers, and Aeronautical Operational Control personnel use distributed decision making to:

- **Enable user preferences/flexibility, and**
- **Increase system capacity, and**
- **Meet air traffic management requirements**

The DAG-TM concept is a detailed instantiation of mature-state Free Flight providing the direction for supporting research and development activities.

Whereas NAS 4.0 defines the WHAT?,
DAG-TM determines the WHY?

What is “Distributed” in DAG-TM?



Distribution of:

- **Information**
  (user preferences, airspace state)
- **Decision making**
- **Responsibility**
  - Flow rate conformance / RTA
    (meet required time of arrival)
  - 4D trajectory conformance
  - Separation assurance

DAG-TM Scope and Assumptions

<u>Scope</u>:

- **All flight phases within the continental US**
- **Mature Free Flight target**
  - **2015 Initial Operating Capability**
  - **Transition path (2005-2015)**

<u>Assumptions</u>:

- **Human-centered concept**
  - **Evolution from today's controller / pilot / dispatcher roles**
- **Mixed-equipage:**
  - **No user classes excluded**
  - **Minimize mandated upgrades**
  - **Benefit / reward capabilities that enhance ATM performance**

DAG-TM Approach

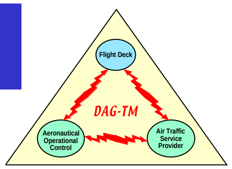
- **Concept development… develop a “gate-to-gate” concept by:**
  - **Spanning a matrix (space) of gate-to-gate “problems”**
  - **Formulating DAG-TM-based concept “solutions” for each problem**

  Concept elements are possible modes of operation within the scope of the RTCA Task Force 3 concept

- **Concept exploration and assessment to refine concept elements and prototype systems into feasible & cost/beneficial solutions.**

- **AATT products resulting from DAG-TM activities:**
  - **Concept definition and assessment**
  - **Concept prototype systems/procedures (air, ground, info., comm.)**
  - **System description/spec’s (function/algorithms, info flow, interfaces)**
  - **Validation results**
  - **Requirements for supporting technologies (e.g., weather, data link…)**
  - **Safety and cost/benefit assessment**

Targeted Benefits



- **Reduced user direct operating costs (time and fuel)**
  - **Flexibility to optimize**
    - » **Trajectories**
    - » **Fleet operations**
- **Increased availability/utilization of user resources**
  - **Increased predictability**
    - » **Greater resource connectivity (crews and equipment)**
    - » **Reduced schedule “buffers”**
- **Increased airspace / airport capacity and throughput**
  - **Reduced constraints due to ATSP (controller) workload**
  - **User-ATM collaboration to reduce/mitigate dynamic problems**
- **Increased ATSP productivity**
- **Distribution of costs for modernization**
- **Fewer impediments to global interoperability**

ATM = Air Traffic Management
ATSP = Air Traffic Service Provider

Matrix (Space) of Operational "Problems"

Matrix dimensions:

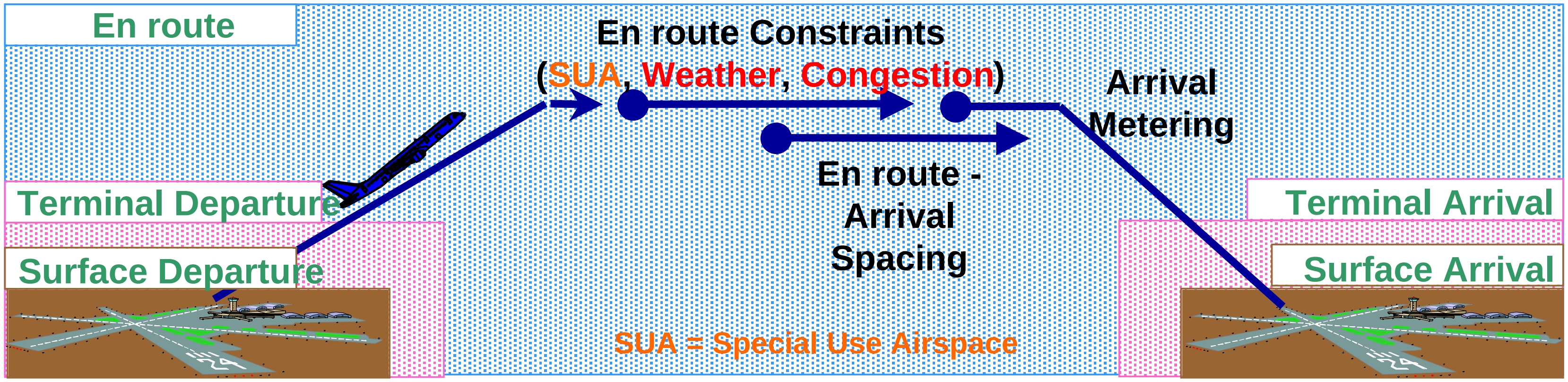
- **Operational Phases:**
  - **Pre-flight**
  - **Departure**
  - **Cruise**
  - **Arrival**
- **US Domestic Airspace Domain:**
  - **Surface**
  - **Terminal**
  - **En route**
- **Dynamic Problems:**
  - **Separation assurance**
  - **Flow constraints**
    - » **Airspace constraints (SUA, weather, complexity/congestion)**
    - » **Transition constraints (arrival metering for airport congestion)**

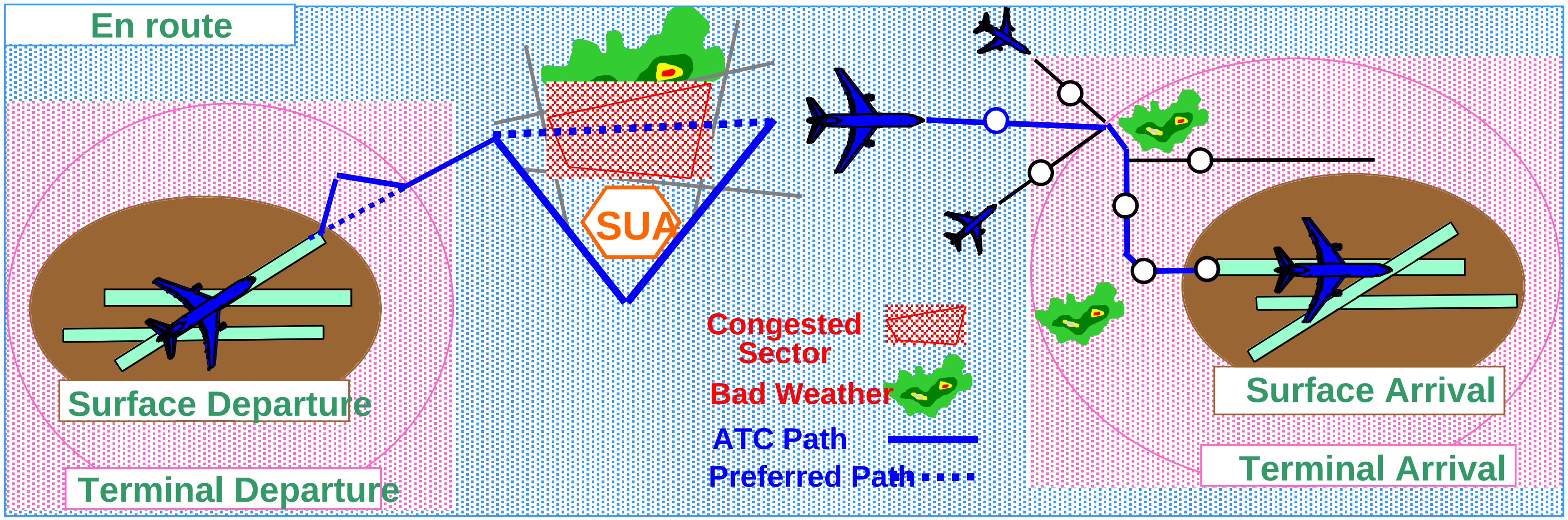
DAG-TM will focus on solving domestic US airspace problems with consideration for the flight deck requirements to facilitate global interoperability.

- Oceanic
- European
- Under-developed

SUA = Special Use Airspace

Set of Airspace Problems





"Complementary" Concept Elements

Pursuit of complimentary concept elements will lead to the best solutions in terms of feasibility, cost/benefit, and transition.

Concept Elements

Over-arching

Gate-to-Gate:
- CE-0 Data Exchange

Pre-flight

Pre-flight Planning:
- CE-1 User optimization for Constraints

Flight Operations

Surface Departure:
- CE-2 Intelligent [Taxi] routing

Terminal Departure:
- CE-3 Free Maneuvering for Separation
- CE-4 Trajectory Negotiation for Separation

En route: (Separation and local-TFM Conformance)
- CE-5 (a/b) Free Maneuvering
- CE-6 (a/b) Trajectory Negotiation

En route: (local-TFM)
- CE-7 Collaboration for SUA/Wx/Complexity

En route / Terminal: (local-TFM)
- CE-8 Collaboration for Arrival Metering

Terminal Arrival:
- CE-9 Free Maneuvering Around Weather
- CE-10 Trajectory Up link [to avoid] Weather

Terminal Arrival:
- CE-11 Self Spacing for Accurate Merge
- CE-12 Trajectory Exchange for Accurate Merge

Terminal Approach:
- CE-13 Closely Spaced Approaches

Surface Arrival:
- CE-14 Intelligent [Taxi] Routing

TFM = Traffic Flow Management

Data Exchange (CE-0)

(over-arching)

- **Problem:**

  Inefficiencies in NAS operations due to the lack of timely and accurate NAS information to stakeholders

- **Solution:**

  Provide timely and accurate data to stakeholders including:

  - » **Weather and 4D winds/temperatures**
  - » **Airspace status (SUA, delays, flow initiatives)**
  - » **User intent (flight deck and AOC)**

- **Benefits:**

  Increased efficiency and productivity for stakeholders

User-optimization for NAS Constraints (CE-1)

(pre-flight planning)

- **Problem:**

  Inadequate accommodation of user preferences (route, altitude, time) due to static and dynamic constraints in the NAS

- **Solution:**
  - **ATSP provides Users (AOC) with current/predicted state of the NAS**
    - » **Airspace/airport delays and flow initiatives**
    - » **SUA status**
  - **Users plan flights with consideration for NAS constraints**
  - **ATSP-User collaborate to enable user preferences while safely addressing dynamic constraints within the NAS**

- **Benefits:**

  Increased flexibility and user efficiency (fuel, time, schedule)

Data link & Intelligent Routing Algorithms (CE-2)

(surface - departure)

- **Problem:**

  Excess taxi-out time due to queuing for runway and ground traffic

- **Solution:**
  - **User/ramp data links estimated departure time to ATSP Intelligent Ground System (IGS)**
  - **IGS determines pushback time to:**
    - » **Minimize departure queue at runway**
    - » **Optimize/balance runway assignment & intersection/runway crossings**
  - **Pushback/departure times data linked to appropriate user (flight deck), ramp, tower, and TRACON DST and supporting positions.**

- **Benefits:**

  Decreased taxi time, departure delays, and emissions

Free Maneuvering for Separation (CE-3)

(terminal - departure)

- **Problem:**
  Inefficient departure routing due to static restrictions for separation
- **Solution:**
  - Flight deck ensures separation via supporting avionics / procedures
  - Equipped aircraft select departure path / climb profile in real time within designated terminal airspace
  - ATSP monitors operations (via supporting Decision Support Tools) and supports separation for non-equipped aircraft
- **Benefits:**
  - Increased user flexibility / efficiency (preferred departure routing)
  - Reduced voice communications

Trajectory Negotiation for Separation (CE-4)

(terminal - departure)

- **Problem:**

  Inefficient departure routing due to static restrictions for separation

- **Solution:**
  - **User and ATSP negotiate (via automation) for efficient departure paths**
  - **User-ATSP exchange data (e.g., aircraft state) for improved predictions**
  - **ATSP leverages enhanced DST capabilities to plan paths and accommodate user preferences**

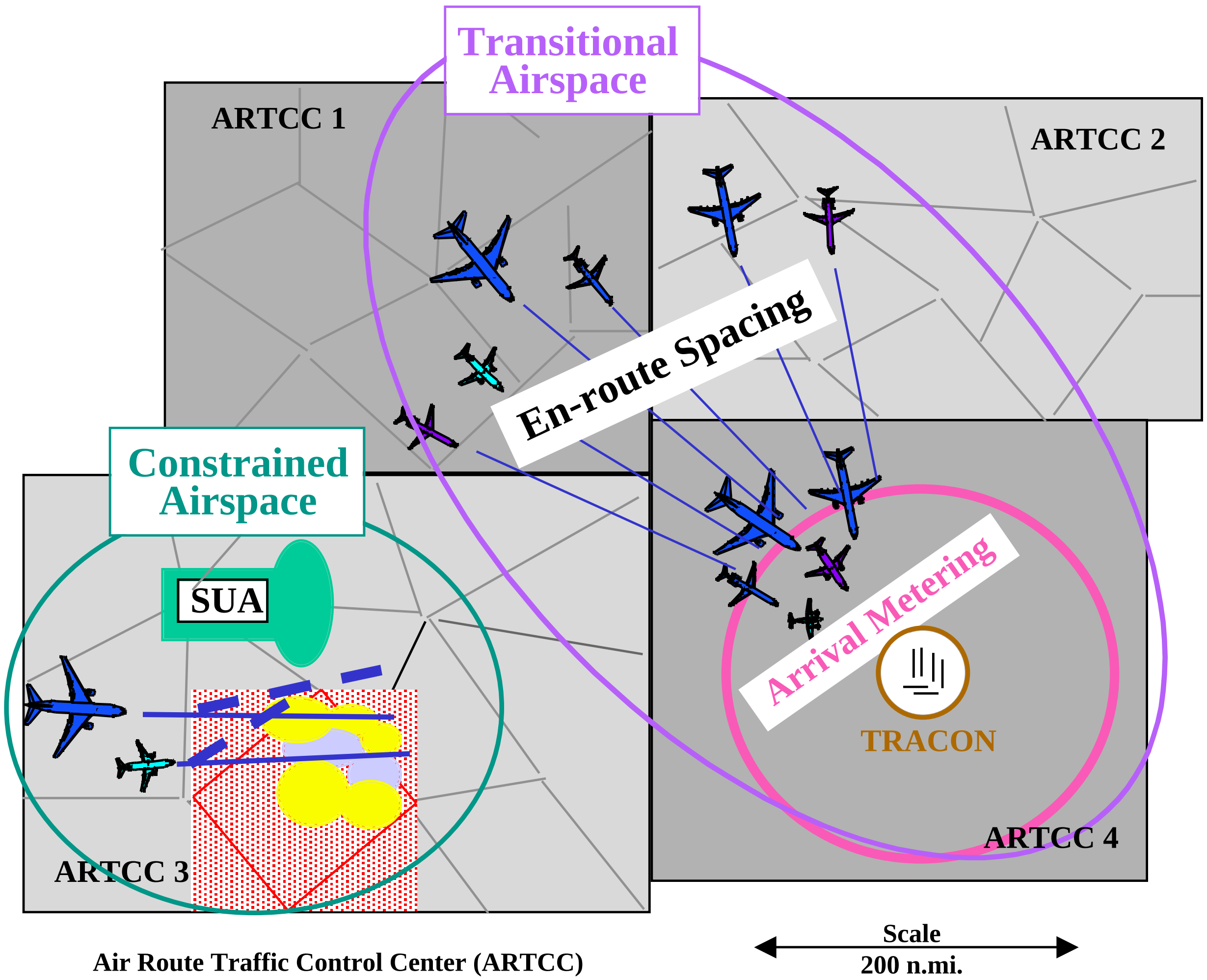
- **Benefits:**
  - **Increased user flexibility / efficiency (preferred departure routing)**

En route Concept Elements

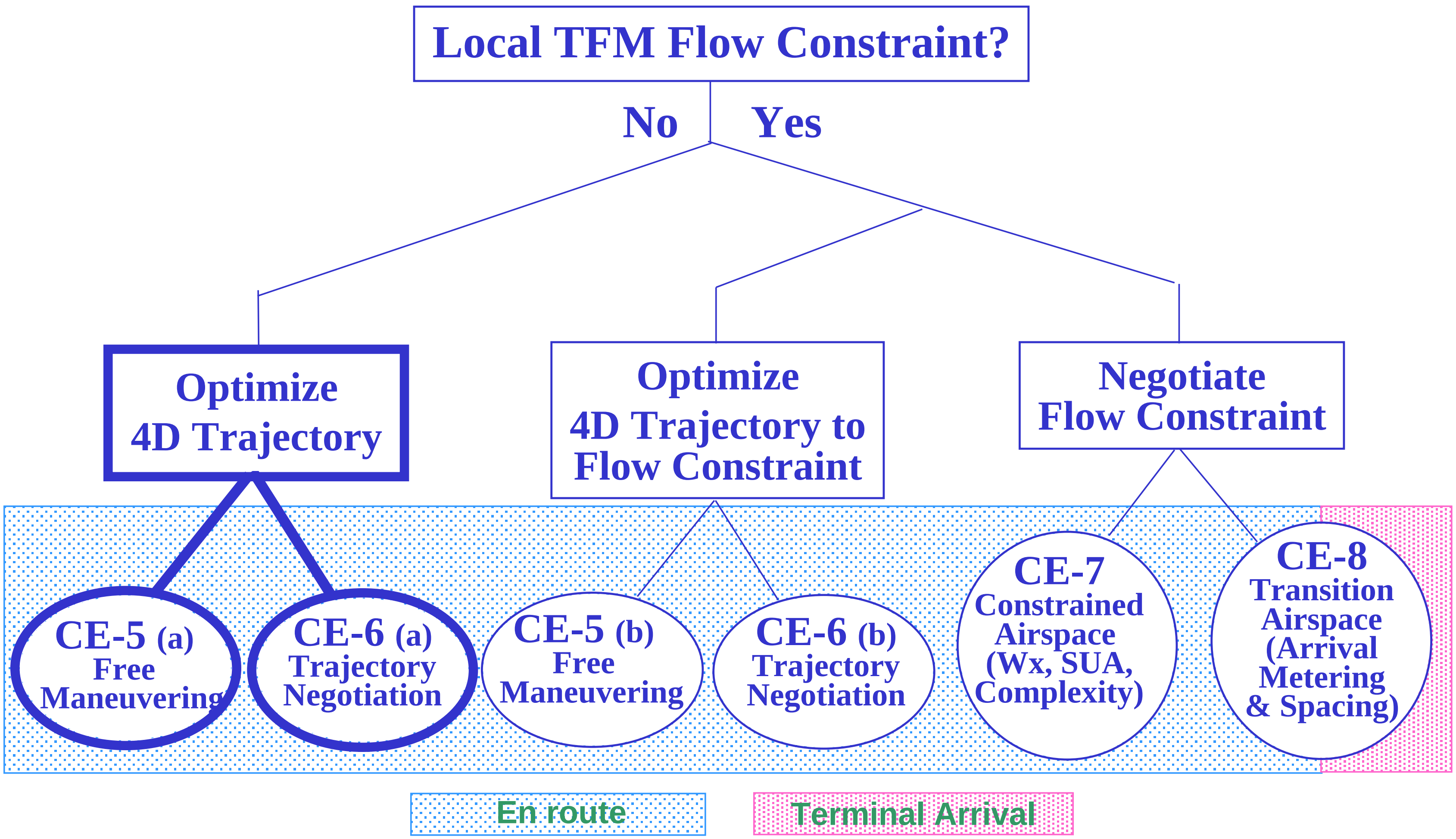
- Four Concept Elements (5, 6, 7, 8) related to en route operations
- Introduction
  - Constrained and Transition Airspace Problems
  - Mapping of Concept Elements
    - » Air Traffic Control (conformance with separation and TFM)
    - » Traffic Flow Management (TFM)

Transitional and Constrained En route Airspace

Integration of Flow-rate Conformance and Separation Assurance



Mapping of En route Concept Elements 5-8



TFM = Traffic Flow Management

Free Maneuvering for User-preferred Separation Conformance (CE-5a)

(en route)

Problem (concept elements 5a & 6a):

Potential traffic separation conflicts often cause ATSP-issued deviations that are excessive or not preferred by users

Solution:

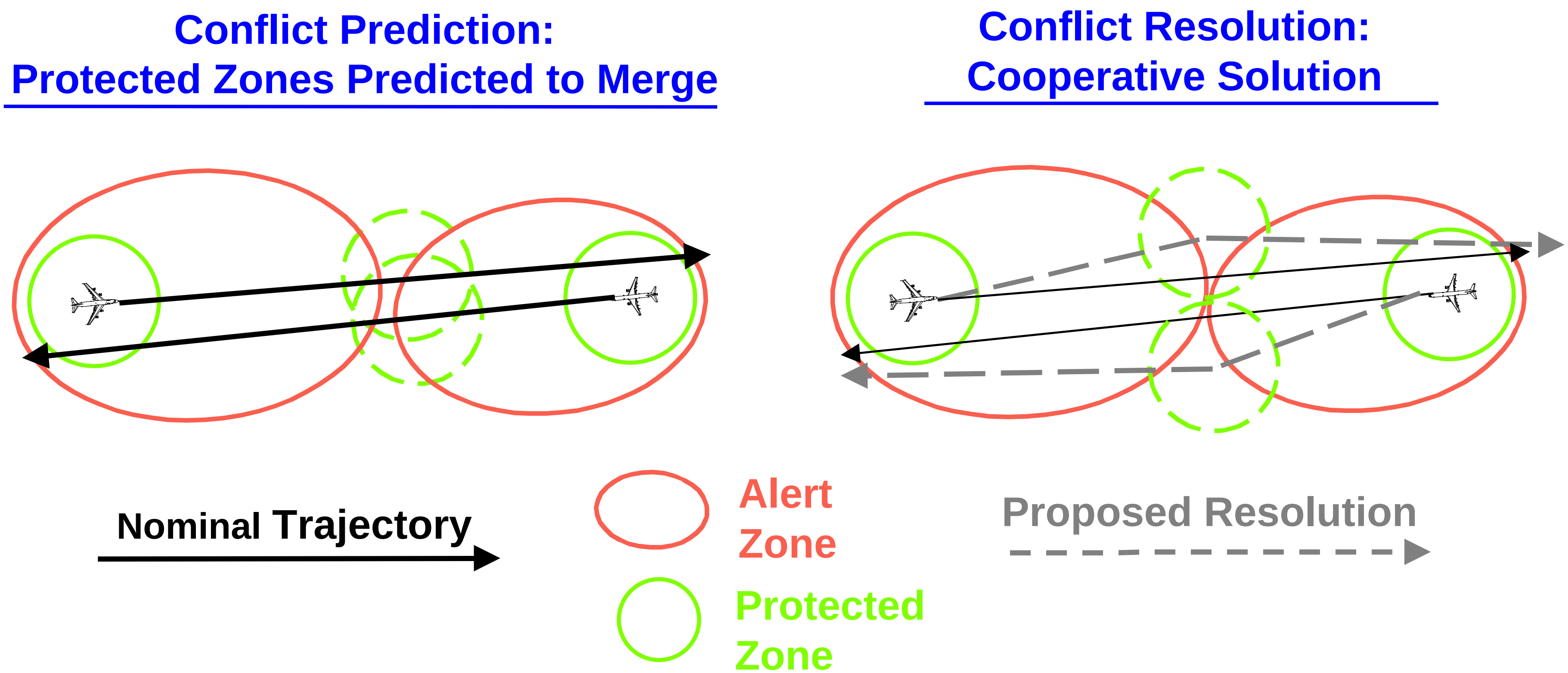
- **Air: Equipped aircraft maneuver freely for separation assurance**
- **Ground: ATSP monitors separation (with complementary ground-based tools) and provides separation assurance for non-equipped aircraft**

Benefits:

- **Increased safety in separation assurance**
- **Increased user flexibility / efficiency (preferred trajectory)**
- **Reduction in excess separation buffers**
- **Reduced voice communications**

Free Maneuvering for User-preferred Separation Conformance (CE-5a)

(en route)



Trajectory Negotiation for User-preferred Separation Conformance (CE-6a)

(en route)

Problem (concept elements 5a & 6a):

Potential traffic separation conflicts often cause ATSP-issued deviations that are excessive or not preferred by users

Solution:

- **User and ATSP negotiate for efficient resolution of conflicts**
- **User-ATSP data exchange** (intent, winds) **for improved trajectory prediction**
- **ATSP uses enhanced DSTs with Conflict Detection & Resolution (CD&R) capabilities**

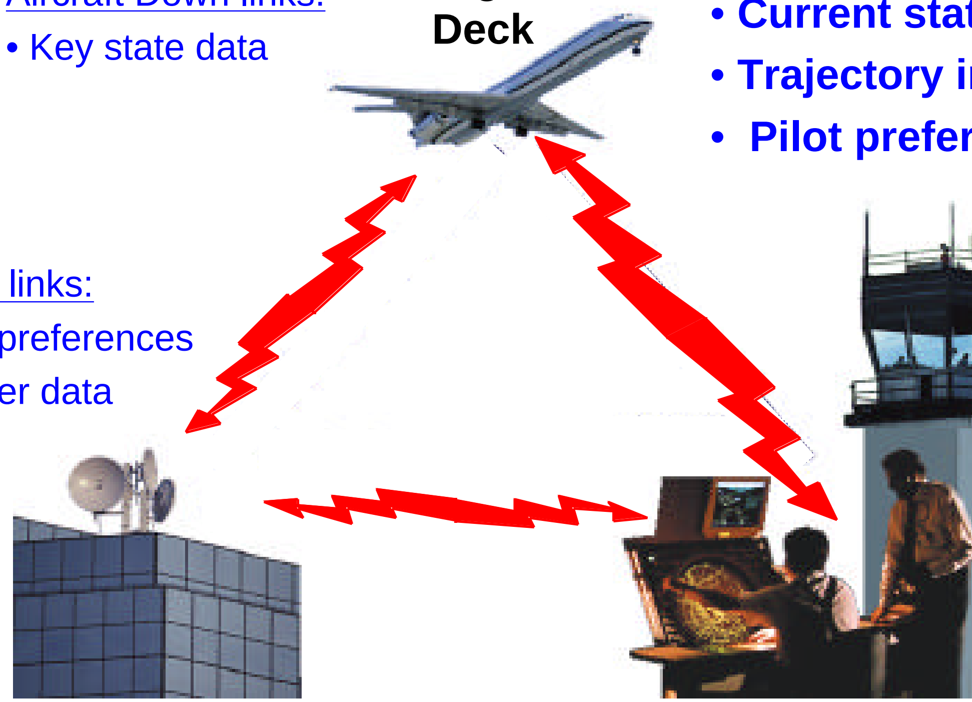
Benefits:

- **Increased user efficiency via improved conflict detection & resolution**
  - » **Reduction in unnecessary deviations due to false-alarm conflicts**
  - » **More time for conflict resolution due to earlier conflict detection**
- **Reduction in ATSP workload for maintaining traffic separation**

Trajectory Negotiation for User-preferred Separation Conformance (CE-6a)

(en route)

Flight Deck



Aircraft Down links:
- Key state data

Aircraft Down links:
- **Current state**
- **Trajectory intent**
- **Pilot preferences/constraints**

AOC Up links:
- Airline preferences
- Key user data

ATSP Up links:
- **Winds on path**
- **Trajectory constraints**
- **Relevant Flight & Traffic Information**

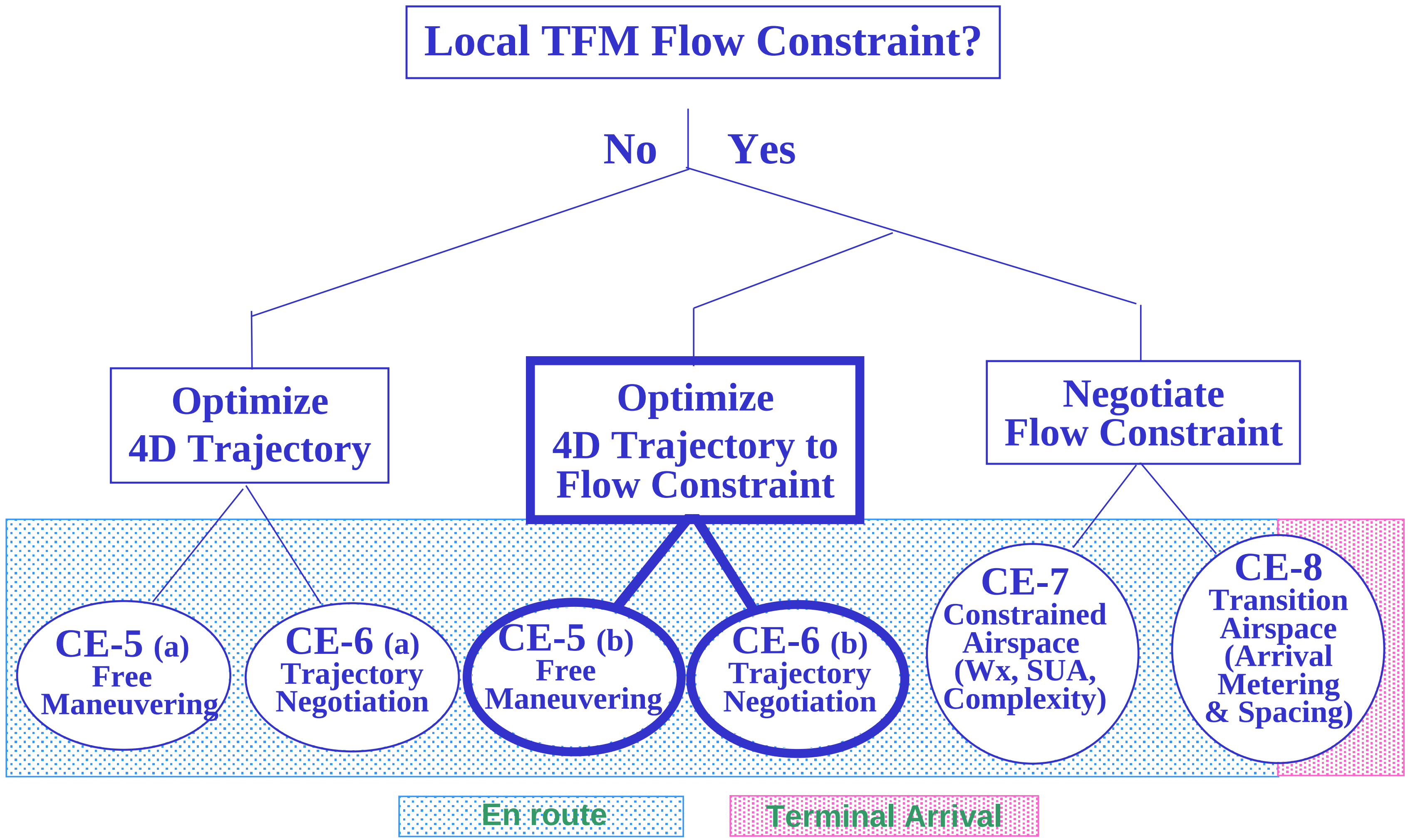
Airline Operational Control

AOC Ground links:
- Airline preferences
- Key flight data

Air Traffic Control

ATSP Ground links:
- Relevant NAS state information

Mapping of En route Concept Elements 5-8

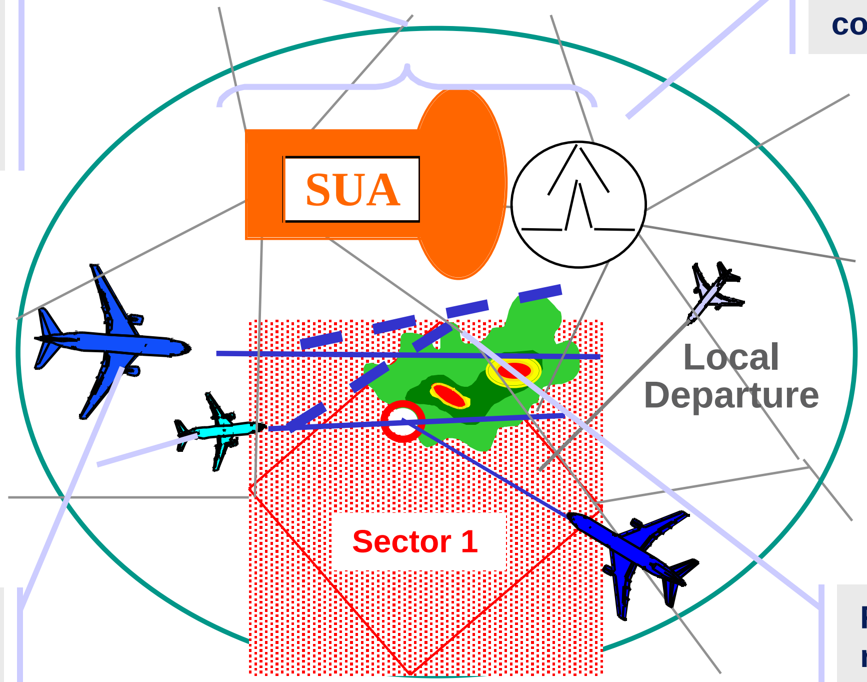


TFM = Traffic Flow Management

Constrained Airspace Challenges

Plan across multiple sectors and multiple facilities,
- involving several human planners
- using best available information

Maintain passenger comfort



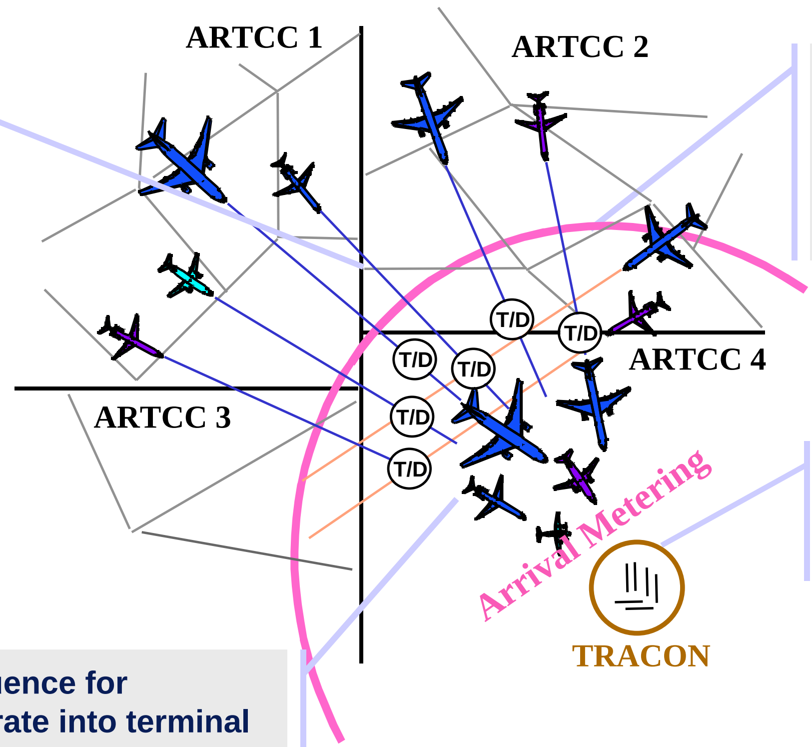
Maintain separation with other aircraft, which may have significantly different performance and navigation capability

Reroute around weather & restricted airspace while avoiding bottlenecks0

Transitional Airspace Challenges

Comply with
inter-facility
flow management
constraints
(en route spacing)

Plan and execute
conflict-free
user-preferred
arrival trajectories.



Comply with terminal flow management constraints (miles-in-trail or metering)

Merge and sequence for
maximum flow rate into terminal

T/D Top of Descent

Free Maneuvering for User-preferred Local-TFM Conformance (CE-5b)

(en route)

Problem (concept elements 5b & 6b):

ATSP cannot accommodate trajectory change requests due to workload; and ATSP-issued clearances are often not preferred by users

Solution:

– Air: Equipped aircraft maneuver freely for separation & local-TFM conformance
   » Trajectories account for the latest weather, SUA, and local TFM constraints for airport/airspace capacity (e.g., scheduled time-of-arrival (STA))

– Ground: ATSP establishes any necessary flow constraints (e.g., STA), and:
   » Monitors the traffic situation and intervenes as necessary
   » Assures separation and local-TFM conformance for unequipped aircraft

Benefits:

– Same as concept element 5a, plus

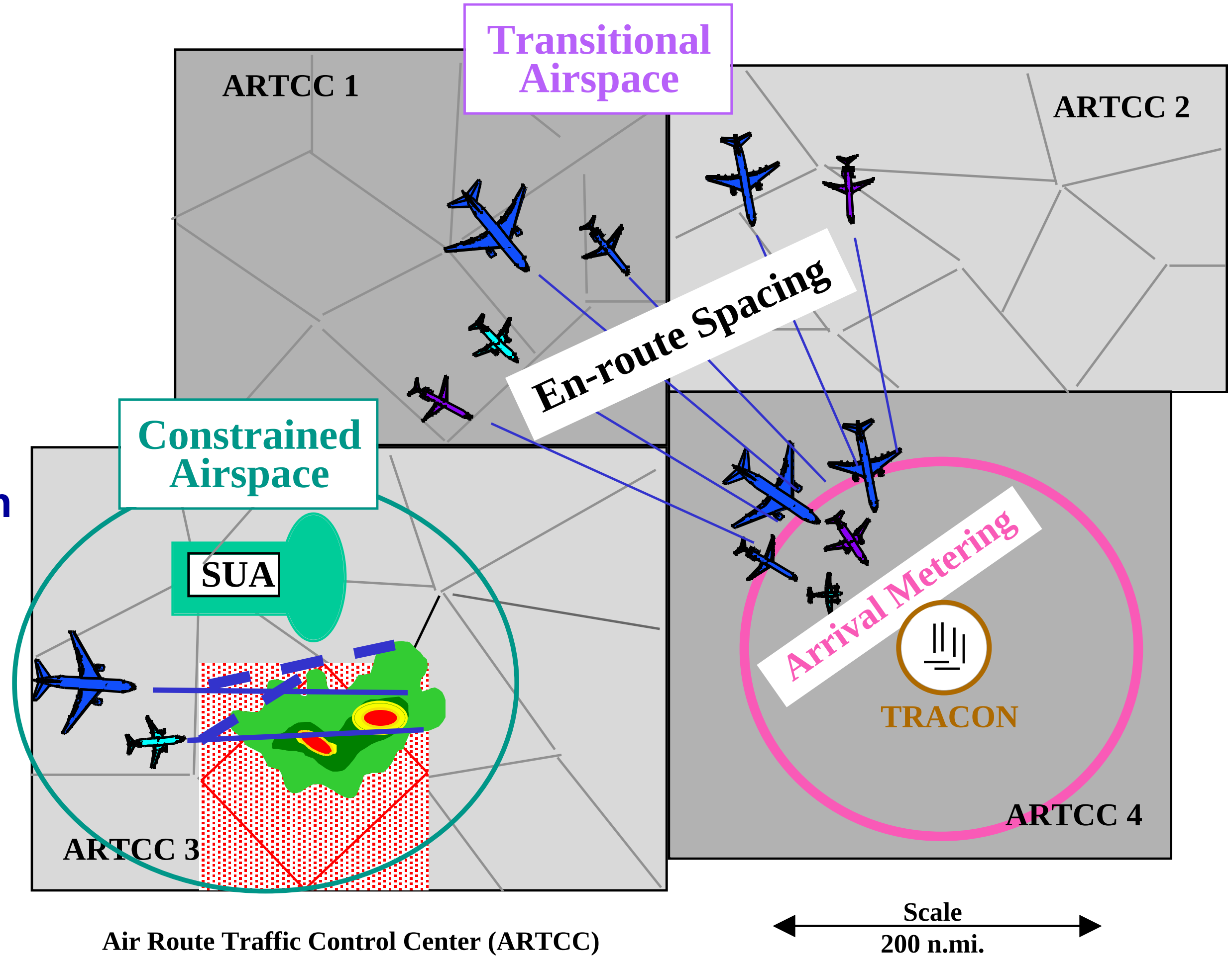
– Increased user flexibility/efficiency in the presence of dynamic constraints

Free Maneuvering for User-preferred Local-TFM Conformance (CE-5b)

(en route)

Equipped Aircraft are free to maneuver for:

- Separation Assurance
- User-preferred conformance with local TFM constraints (route / time restrictions) due to:
  - Arrival metering / spacing
  - Airspace congestion
  - Wx, SUA



Trajectory Negotiation for User-preferred Local-TFM Conformance (CE-6b)

(en route)

Problem (concept elements 5b & 6b):

ATSP cannot accommodate trajectory change requests due to workload; and ATSP-issued clearances are often not preferred by users

Solution:

User and ATSP negotiate for user-preferred trajectory changes:

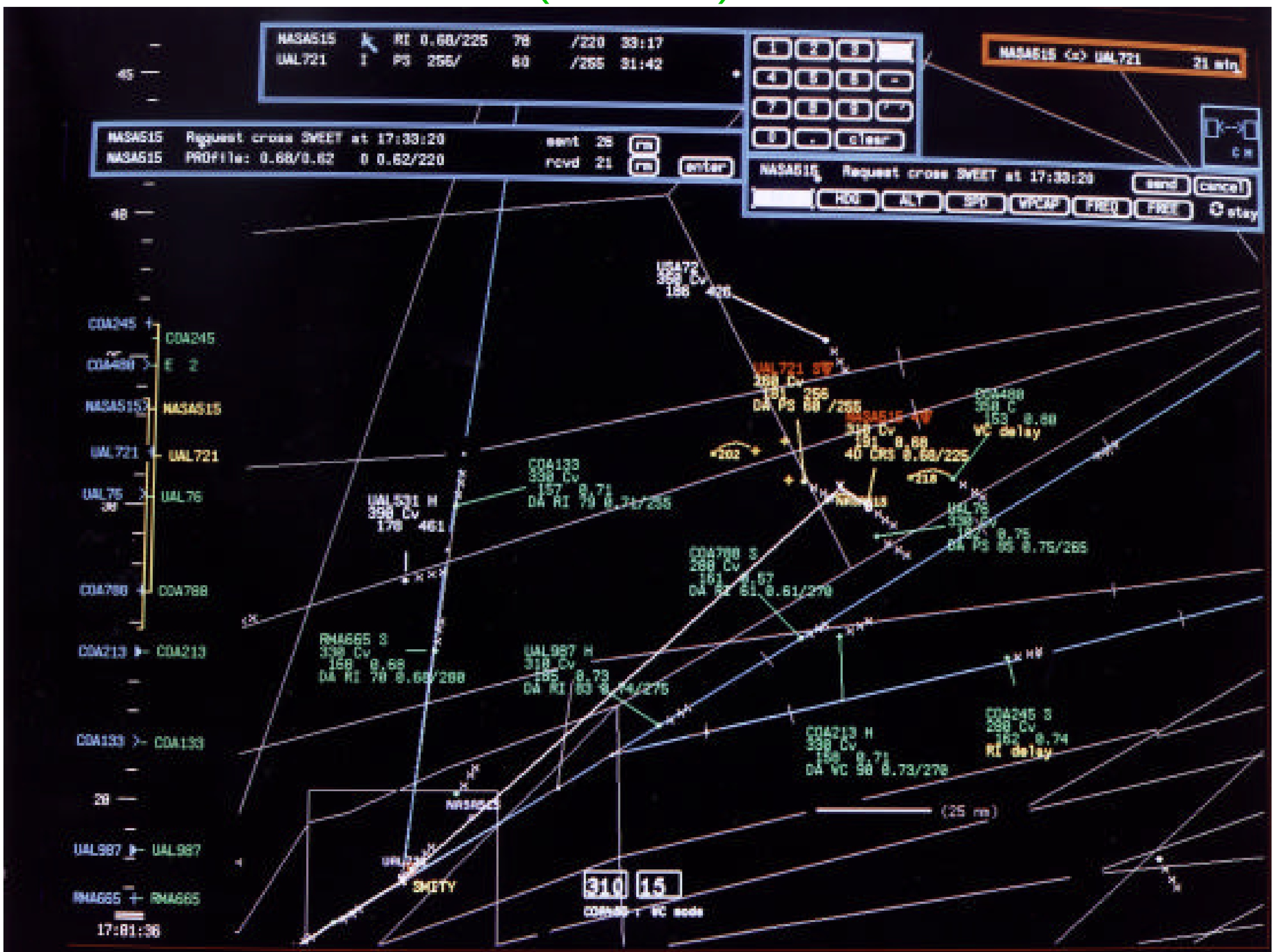
- » **User formulates preferred trajectory changes, based on the latest weather, SUA, and local TFM constraints (e.g., STA), and transmits it to the ATSP.**
- » **ATSP evaluates trajectory change request for approval. If not approved, ATSP transmits additional constraints or issues an alternative trajectory.**

Benefits:

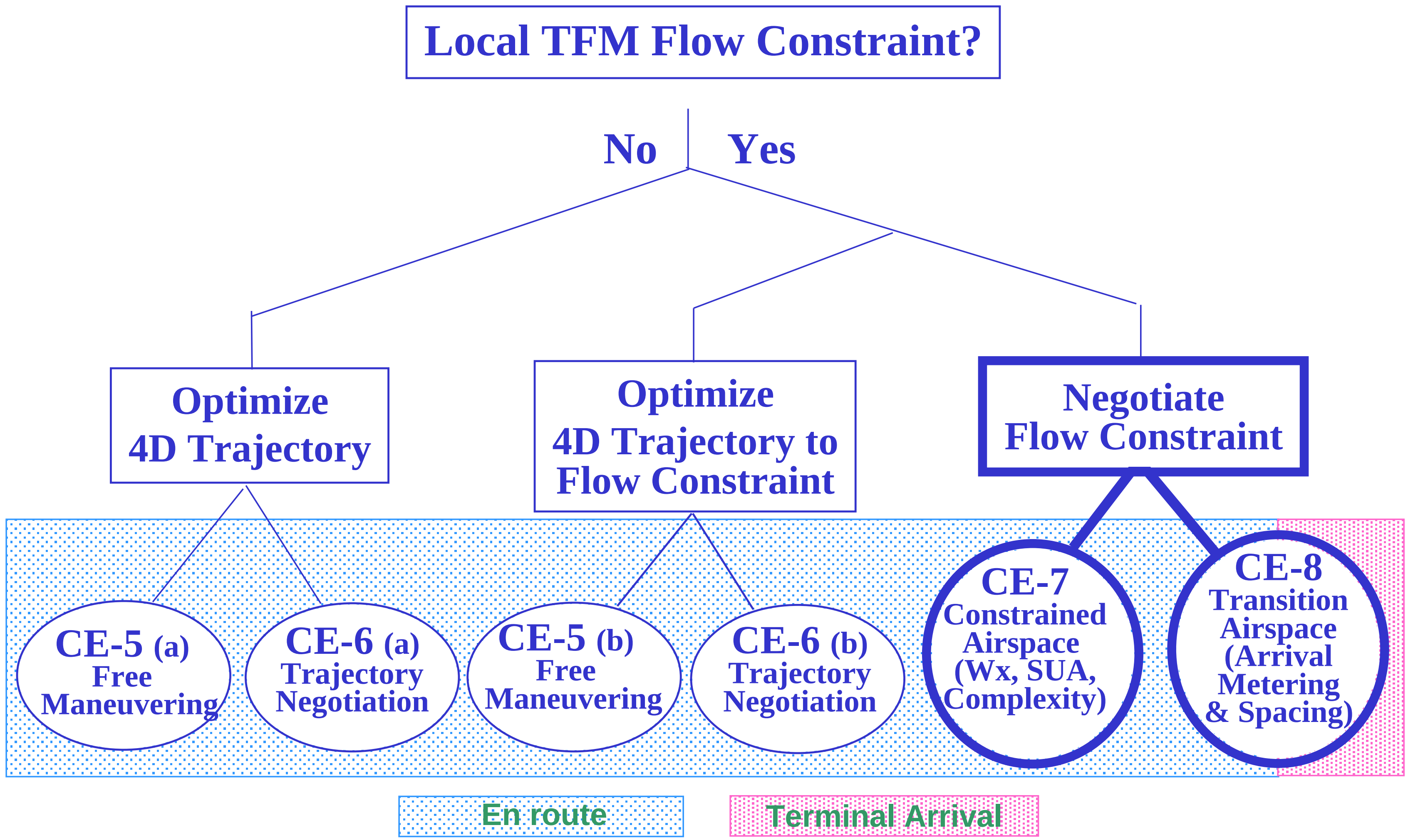
- **Same as concept element 6a, plus**
- **Increased user flexibility/efficiency in the presence of dynamic en route constraints**

Trajectory Negotiation for User-preferred Local-TFM Conformance (CE-6b)

(en route)



Mapping of En route Concept Elements 5-8



TFM = Traffic Flow Management

Collaboration for Wx, SUA, and Complexity Constraints (CE-7)

(en route - TFM)

Problem:

Excessive and un-preferred local-TFM deviations due to inefficient use of en route airspace

Solution:

- Provide the user with timely and accurate predictions of the state of the NAS (Weather, SUA activation, & airspace complexity constraints)
- Improve the prediction accuracy of NAS state
- Develop DSTs and procedures to:
  - » Improve local-TFM decisions and User plans/preferences (AOC & aircraft)
  - » Facilitate collaboration on the:
    - Type, extent, and implementation of local TFM initiatives (Users & ATSP)
    - Dynamic access to SUA (SUA authorities, ATSP, & Users)

Benefits:

- Increased user flexibility/efficiency in congested en route airspace
- Increased ATSP productivity and improved control of sector workload

Collaboration for Wx, SUA, and Complexity Constraints (CE-7)

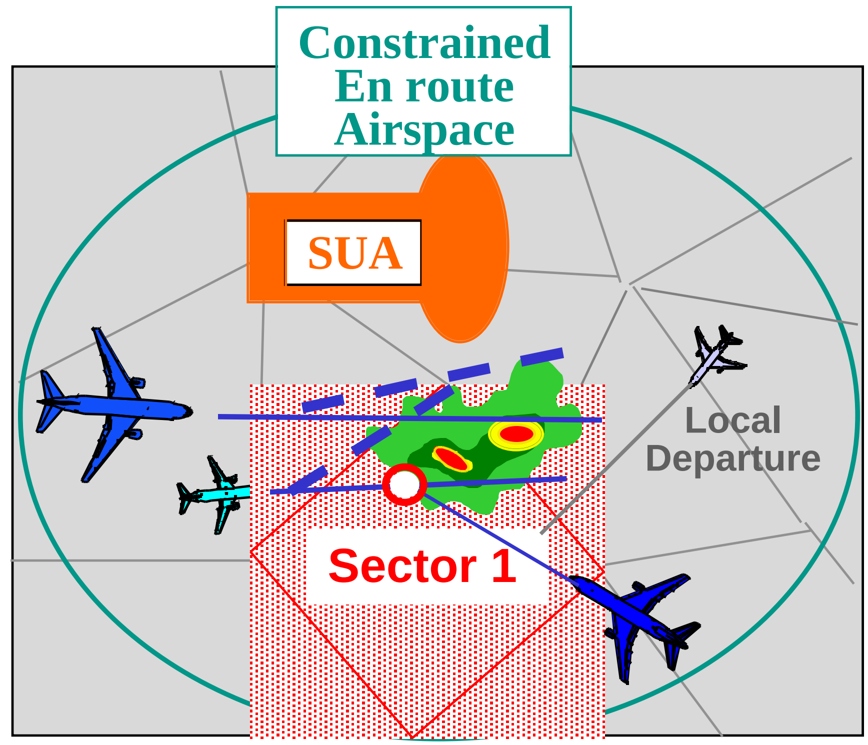
(en route - TFM)

Congested Airspace
Airspace / sector complexity (dynamic density) is predicted to exceed acceptable levels

Planned Path (airborne)

Planned Path (pre-departure)

Predicted Conflict



En route Air Route Traffic Control Center

Collaboration for Arrival Metering (CE-8)

(en route - TFM)

- **Problem:**

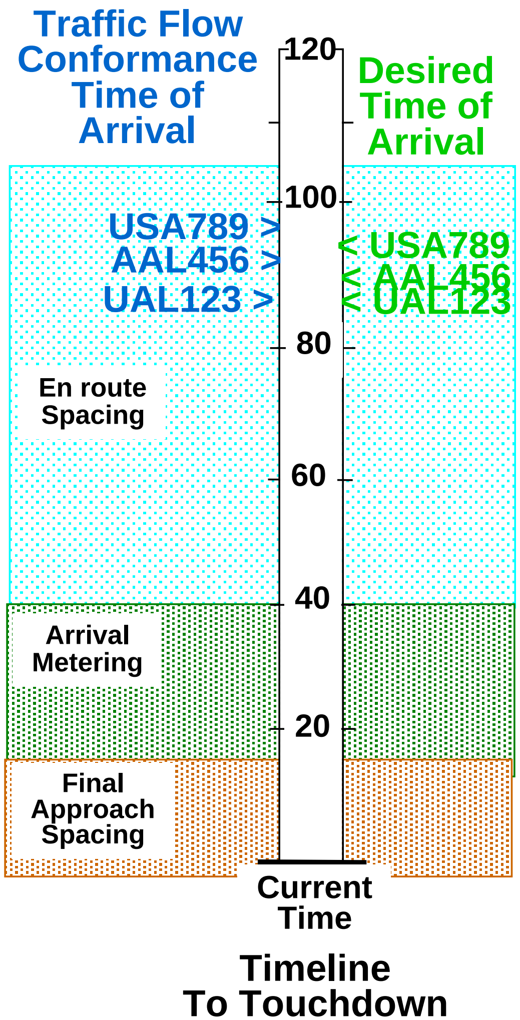
  ATSP arrival metering/spacing often does not account for user preferences [3 phases: en route, extended terminal area, and terminal]

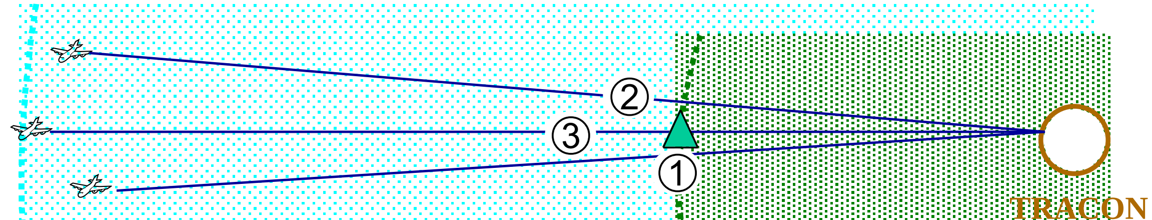
- **Solution:**
  - **Users determine / data link their arrival preferences based on the predicted status of the NAS:**
    - » **Preferences include (depending on the arrival metering/spacing phase): Arrival Time, Arrival Routing / Metering Fix, Sequence, and Runway**
  - **En route/Terminal ATSP(s) use DST(s) to generate metering/spacing constraints (e.g., Scheduled Times of Arrival (STA)) that accommodate user preferences considering fairness, efficiency, and sector workload**

- **Benefits:**
  - **Increased user flexibility/efficiency/predictability at congested airports**

Collaboration for Arrival Metering (CE-8)

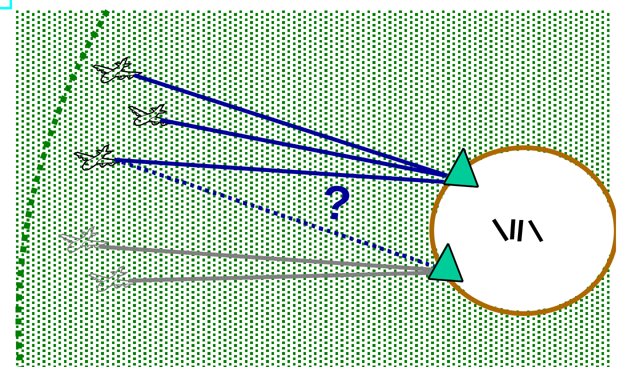
(en route - TFM)





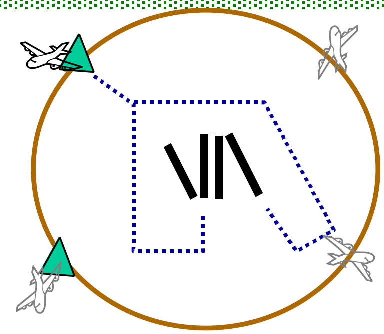
User Preferred En route Spacing

- Desired Time of Arrival / Sequence
- Spacing Fix



User Preferred Arrival Metering

- Desired Time of Arrival / Sequence
- Metering Fix
- Runway



User Preferred Final Spacing

- Desired Time of Arrival / Sequence
- Runway

Free Maneuvering for Weather Avoidance (CE-9)

(terminal - arrival)

- **Problem (concept elements 9 and 10):**

  Inefficient terminal re-routing to accommodate dynamic airspace constraints such as weather

- **Solution:**
  - **ATSP determines sequence and scheduling constraints**
  - **Equipped aircraft may maneuver freely, to avoid weather, within bounds determined by the ATSP**
    - » **Appropriately equipped aircraft may self space behind "free-maneuvering leaders"**

- **Benefits:**
  - **Increased arrival capacity/throughput in foul weather**
  - **Increased flexibility and user efficiency**
  - **Reduced ATSP workload**

ATSP Trajectory Up link for Weather Avoidance (CE-10)

(terminal - arrival)

- **Problem** (concept elements 9 and 10):

  Inefficient terminal re-routing to accommodate dynamic airspace constraints such as weather

- **Solution:**
  - ATSP leverages DSTs and ground-based weather tools to:
    - » Determine sequence and scheduling constraints
    - » Plan and up link a conflict-free trajectory to avoid weather
  - Aircraft leverages avionics for trajectory planning and weather to:
    - » Analyze the the ATSP trajectory up link for safety/acceptance, and
    - » Accurately conform to the ATSP trajectory
    - » Possible collaboration with ATSP for user-preferred trajectory clearance

- **Benefits:**
  - Increased arrival capacity/throughput in foul weather
  - Increased flexibility and user efficiency
  - Reduced ATSP workload

Self Spacing for Merging and In-Trail Separation (CE-11)

(terminal - arrival)

Problem (concept elements 11 and 12):

Excessive spacing buffers on final approach reduce arrival throughput and airport capacity

Solution:

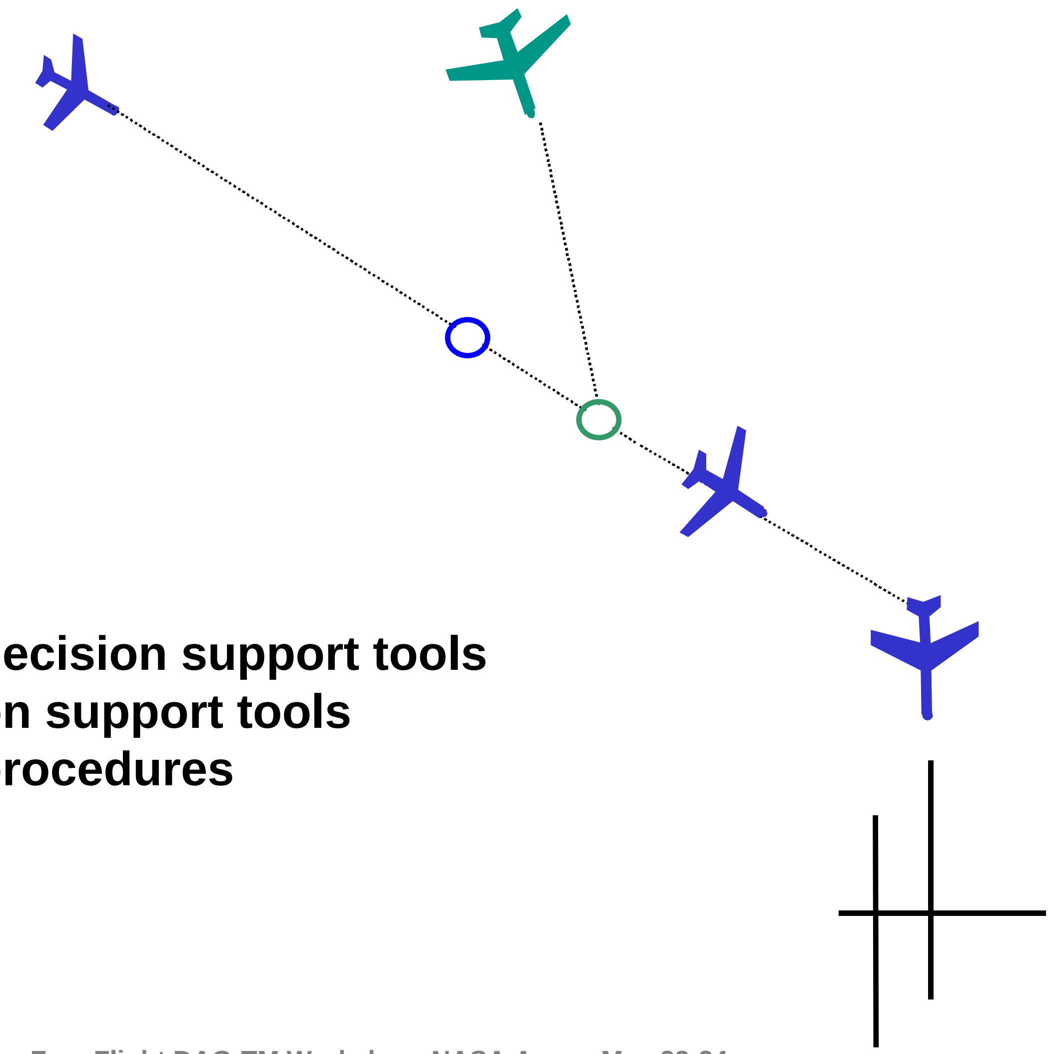
- Appropriately equipped aircraft are cleared to maintain separation relative to a leading aircraft:
  - » flight deck displays and guidance for:
    - Self spacing and merging
    - Fine tuning of fixed-time spacing
- ATSP displays & procedures for shared separation responsibility

Benefits:

- Increased arrival throughput
- Enhanced ATSP & pilot shared understanding of traffic management plan

Self Spacing for Merging and In-Trail Separation (CE-11)

(terminal - arrival)



Enhanced CNS
New flight deck decision support tools
New ATM decision support tools
New air-ground procedures

ATSP Trajectory Exchange for Accurate Merging/Spacing (CE-12)

(terminal - arrival)

Problem (concept elements 11 and 12):

Excessive spacing buffers on final approach reduce arrival throughput, especially in foul weather

Solution:

- Basic exchange of data between aircraft and ATSP to improve the accuracy of aircraft and ATSP DSTs
- ATSP uses terminal DST to plan and control conflict-free trajectories for accurate merging/spacing, and up links the trajectories to aircraft
- Aircraft precisely fly the up linked trajectories to ensure conformance

Benefits:

- Increased arrival capacity/throughput
- Reduced ATSP workload

Airborne CD&R for Closely-Spaced Approaches (CE-13)

(terminal - approach)

Problem:

During instrument meteorological conditions, independent approaches may not be utilized for runways less than 4300 feet apart

Solution:

- Appropriately equipped aircraft may conduct closely-spaced, independent approaches by leveraging on-board avionics, surveillance data & air-ground procedures to ensure safe separation
- ATSP DSTs assist final controllers with missed approach management in case of an abort of a closely-spaced approach

Benefits:

- Increased arrival capacity/throughput

Data link & Intelligent Routing Algorithms (CE-14)

(surface - arrival)

- **Problem:**

  Excess taxi-in time due to queuing for active runway crossings and ground traffic

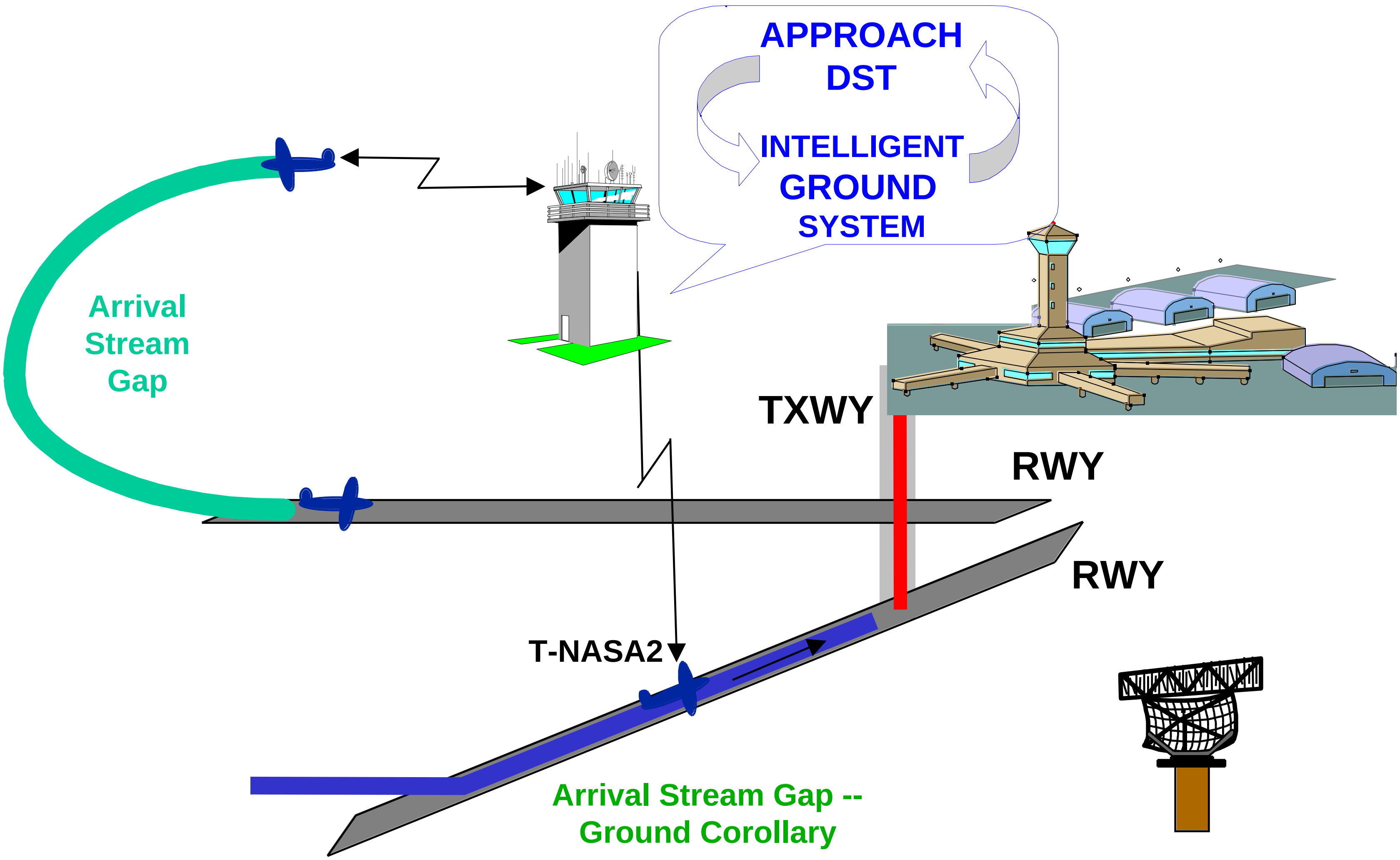
- **Solution:**
  - **Approach DST passes touchdown time to Intelligent Ground System (IGS)**
    - » **IGS optimizes intersection crossings and active-runway crossings**
    - » **IGS passes requirements for gaps in the arrival-stream to the Approach DST**
  - **IGS data links exit and taxi clearance to flight deck on final**
  - **Aircraft lands, exits runway, and accurately taxis on cleared route with efficient crossings of active runways**

- **Benefits:**

  Decreased taxi time, arrival delays, emissions, and user/ATSP workload

Data link & Intelligent Routing Algorithms (CE-14)

(surface - arrival)



Collaborations and Partnerships

- **FAA (AND, WJHTC, other?)**
  - CNS-ATM, CPDLC, Air/ground integration simulations
  - Technical Transfer
- **Labs**
  - MITLL
  - NOAA
  - National Aerospace Laboratory of the Netherlands (NLR)
    - Concept Development and Applied Human Factors
- **RTCA**
  - SC186 Work Group 2, (Conflict Detection and Resolution Subgroup)
  - SC186 Work Group 4 (Airborne architecture)
  - SC194 Work Group 2 (Flight Operations and ATM Integration)
- **Cargo Airline Association**
  - Safe Flight 21 Ohio Valley ADS-B Op Evaluation and future efforts
- ***Under Exploration:***
  - MITRE/CAASD
  - Eurocontrol Experimental Centre (Bretigny)
  - Northern European ADS-B Network Update Program
  - Gulf of Mexico

DAG TM Status

- **Completed DAG TM Concept Definition and High-level Research Plan documents September 30, 1999**
  - **Concept Definition is released for distribution (web site)**
  - **Research Plan in signature process for release**
- **Presented Concept and High-level Research Plan to NASA ATM Executive Steering Committee (ESC), October 21, 1999**
  - **Response favorable**
  - **Committee recommended priority effort**
- **Initial AATT project funding analysis cut CE 14 (Surface Arrival)**
- **Detailed CE project/resource plans developed, March 2000**
- **Final AATT budget/plan revision to incorporate DAG, pending.**
- ***Industry Workshop (May 22-24) at NASA Ames… JOIN US!***

Research & Development Status

Free Maneuvering (CE 5a & 5b)

- **Initial concepts defined**
  - Requirements-driven, integrated equipage operations (Langley contract)
  - Technology-driven, integrated equipage operations (Langley contract)
  - Unconstrained operations (NLR)
- **Initial study of free maneuvering feasibility**
  - Unconstrained operations separation assurance (NLR, Ames)
  - Air-Ground Integration Experiment (AGIE) study (NASA, WJHTC)
- **Initial technology functionality developed for research studies**
  - Air & ground decision-support displays with integrated conflict detection and resolution algorithms (Langley, Ames, NLR)
  - Conflict detection and resolution algorithms (Ames)
- **Simulation environments developed**
  - Free Flight Simulation (Langley, Ames)
  - Avionics Integration Research Simulation (AIRSIM) (NLR)
  - Traffic and Experiment Manager (NLR)
  - Future ATM Concepts Evaluation Tool (FACET) (Ames)
  - Air-Ground Integration Experiment (AGIE) capability (NASA, WJHTC)

Feasibility research on Unconstrained Operations ~80% complete.
Initiating feasibility research on Constrained Operations.

Research & Development Status

Trajectory Negotiation (CE 6a & 6b)

- **Initial concepts defined and explored for data exchange and trajectory negotiation**
  - integration of 4-D ATSP advisories with 4-D FMS guidance and control
  - 4-D trajectory negotiation between an FMS and ATSP automation
  - air/ground information exchange for calibrating and improving the accuracy of ATSP and FMS trajectory predictions

- **Studies on trajectory prediction and conformance**
  - conformance accuracy of actual aircraft trajectories with ATSP predictions, for both FMS and non-FMS equipped aircraft
  - availability of pre-departure information from user systems for use in improving ATSP trajectory predictions
  - current wind prediction accuracy and potential ATM DST performance improvements through downlink of aircraft wind measurements

Collaboration for Wx, SUA, and Complexity Constraints (CE-7)

(en route)

Problem:

Excessive and un-preferred local-TFM deviations due to inefficient use of en route airspace

Solution:

- Provide the user with timely and accurate predictions of the state of the NAS (Weather, SUA activation, & airspace complexity constraints)
- Improve the prediction accuracy of NAS state
- Develop DSTs and procedures to:
  - Improve local-TFM decisions and User plans/preferences (AOC & aircraft)
  - Facilitate collaboration on the:
    - Type, extent, and implementation of local TFM initiatives (Users & ATSP)
    - Dynamic access to SUA (SUA authorities, ATSP, & Users)

Benefits:

- Increased user flexibility/efficiency in congested en route airspace
- Increased ATSP productivity and improved control of sector workload

Collaboration for Wx, SUA, and Complexity Constraints (CE-7)

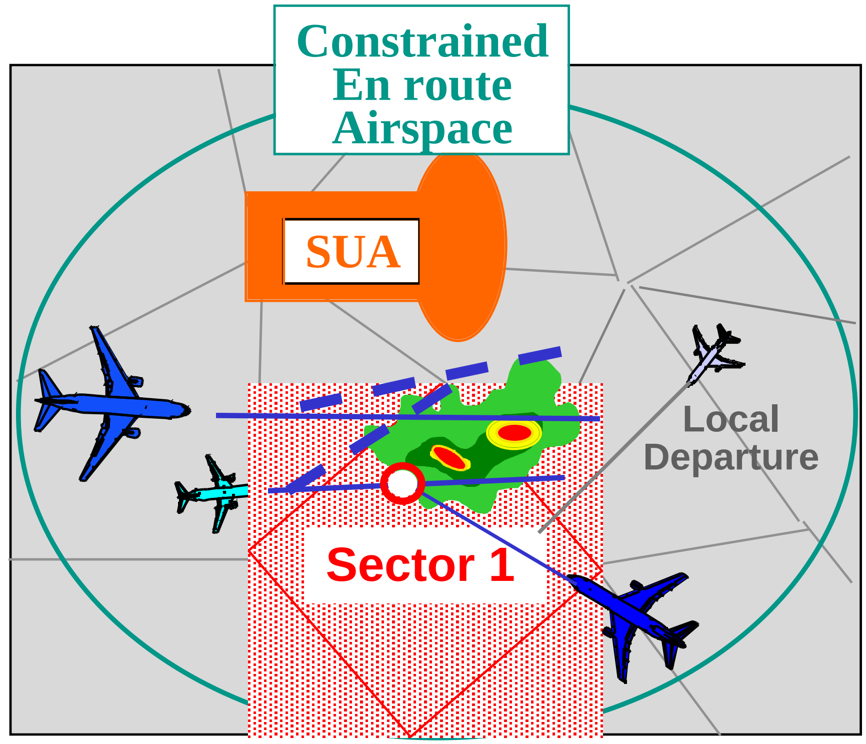
(en route)

Congested Airspace
Airspace / sector complexity (dynamic density) is predicted to exceed acceptable levels

Planned Path (airborne)

Planned Path (pre-departure)

Predicted Conflict



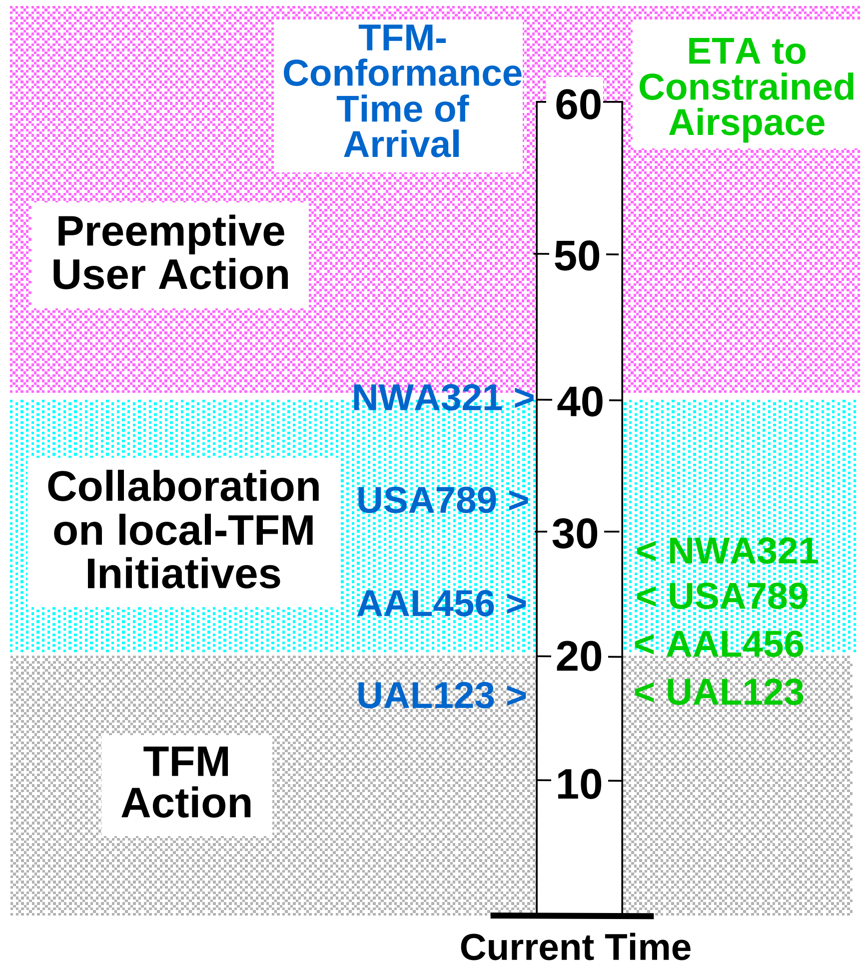
En route Air Route Traffic Control Center

Collaboration for Wx, SUA, and Complexity Constraints (CE-7)

(en route)

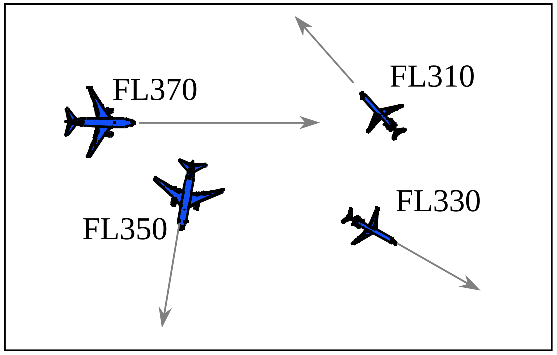
Local Traffic Flow Management

- **Key NAS State:**
  - Sector congestion/complexity (dynamic density)
- **TFM "controls" (initiatives)**
  - Re-routing
  - Spacing
    - » En route
    - » Departure control
  - Dynamic access to SUA
  - Dynamic re-sectorization



Timeline of Sector 1 Traffic Demand

Dynamic / Gaggle Density

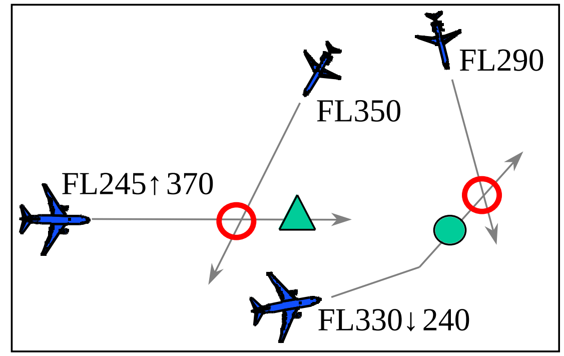


Low Traffic Complexity
(Traffic count = 4)

Dynamic Density

Predictive measure of a sector's traffic complexity

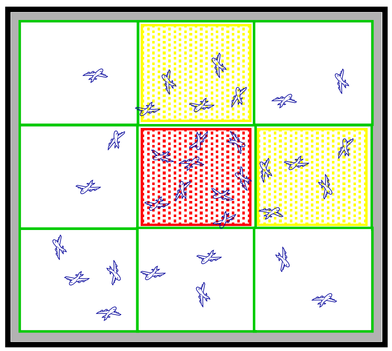
Potential Conflict
Top of Climb (TOC)
Top of Descent (TOD)

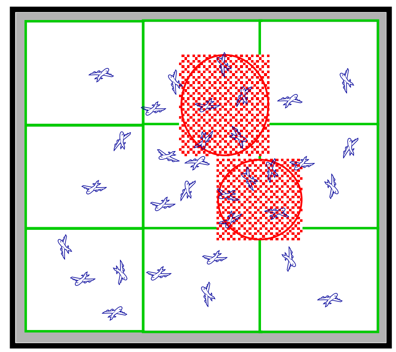


High Traffic Complexity
(Traffic count = 4)

Dynamic Density

Discretized to airspace boundaries…
Prevent sector overload.





"Gaggle" Density

Shrink wrapped to dynamic gaggles…
Method to identify and mitigate regions with congestion exceeding capabilities of air-to-air self separation.

Dynamic Density vs. "Gaggle" Density

Traffic Flow Management tools for preventing un-safe traffic loads

Research & Development Status

Collaboration for Mitigating Constraints (CE 7)

- **Constrained airspace problem defined**
  - Concept proposed for improved TFM with gap analysis of the related R&D activities in the U.S.
  - Context established relative to earlier FAA/TFM concepts and current Free Flight and CDM activities
- **Assessments of TFM strategies**
  - Routing for local congestion and metering for arrival spacing
- **Exploration of collaboration issues/process**
  - National ground delay program and flight plan/re-routing
  - Operational issues / processes for collaboration during flight operations, specifically user-preferred sequences during CTAS arrival metering
- **Constraint measurement and prediction**
  - Dynamic density metric development and validation
  - Weather prediction technology (initiating collaborations)